# The Bacterial and Chemical Inputs to Zion National Park

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## Abstract

Three major streams flow through Zion National Park: the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek. The water quality of these three streams was studied during the summer of 1977. Bacterial indicators and the background water chemistry were measured.

Given the location and frequency of the recreational use of the Park, emphasis was placed on the bacterial concentrations of the North Fork. Water samples were taken both inside and outside the Park to determine bacterial inputs of surrounding areas. It is shown that some upstream uses on private land do have an impact on water quality in the North Fork.

## Introduction

Zion National Park is drained by three major streams, the North and East Fork (of the Virgin River) and LaVerkin Creek. The headwaters of all three streams are located outside the Park. Because the water quality of these streams has been determined in part by land use outside the Park, this study was designed to monitor the water quality entering the Park, and, when possible, to study key areas of water quality degradation outside the Park. The study includes the analysis of both the water chemistry and bacteriology of the three major streams. Emphasis was given to the North Fork because of its heavier recreational use.

### Study objectives

1) To determine the bacterial water quality of the North Fork as it enters Zion National Park.

2) To evaluate land use practices outside the Park as they may influence the water quality of the North Fork.

3) To establish water chemistry baseline data for the North Fork, East Fork and LaVerkin Creek during summer low flows.

4) To present conclusions and recommendations.

## Previous Investigations

Nonpoint sources of pollution are receiving increased attention in wildland water quality management. One of the primary sources of nonpoint bacterial pollution comes from domestic animal grazing. Cattle and sheep grazing contribute to increases in bacterial concentrations of mountain streams; however, the magnitude of this increase varies greatly.

One of the primary factors affecting bacterial inputs is the proximity of the grazing animal to the live stream channel. Kunkle (1970) found that increases in bacterial levels of mountain streams were directly related to the accessability of cattle to the stream. Similar results were found in studies by Morrison and Fair (1966) and Kunkle and Meiman (1967).

In addition to the accessability factor, the simple presence of grazing animals influences wildland water quality. Darling and Coltharp (1973) found significant increases in bacteria concentration in streams directly downstream from cattle and sheep grazing. Skinner et al. (1972) showed a strong correlation between grazing periods and increased bacterial numbers within high mountain watersheds.

There seems little question that grazing does have an impact on wildland water quality; however, there are other factors to be considered. First, Watler and Bottman (1967), and Stuart et al. (1971) have shown that wildlife can also cause increases in stream bacteria levels.

Second, Mack (1974) has demonstrated that bacteria can survive and even multiply in natural waters. This factor complicates the accurate measurement of bacterial inputs--regardless of the nonpoint source. Third, Buckhouse (1975) showed that bacterial life spans can be greatly influenced by the conditions of cattle feces. If the feces are allowed to dry quickly, the associated bacteria become encased within a protective media and may survive there for several years. These all add to the complexity of evaluating the impact of grazing on wildland water quality.

In addition to the above considerations, some bacterial indicators are better than others for monitoring the impact of domestic animal wastes on water quality. Kunkle (1977) used total coliform (TC), fecal streptococci (FS), enterococci and fecal coliform (FC) as the primary indicator organisms. Using a controlled environment, Kunkle found the fecal coliforms to be the most responsive and accurate measurement of cattle feces contamination of wildland waters.

## Sampling Methods

During the summer of 1977 three streams were sampled. Each has headwaters outside Zion National Park and each represents a major surface water resource for the Park. This section discusses the study areas and reasons for their selection, the parameters measured, the sampling sites, the equipment used, and the analysis of data.

### Study area

Figure 1 shows the location of Zion National Park with respect to the three drainage basins. The area of each of these watersheds is given in Table 1.

Table 1. Drainage basin areas for the North Fork and East Fork of the Virgin River and LaVerkin Creek.

| Drainage basin | Area ($miles^2$) |
|---|---|
| North Fork | 364 |
| East Fork | 328 |
| LaVerkin Creek | 41 |

The southwestern section of the Park shows no drainage network. This section has not yet been studied for water quality. The area consists primarily of ephemeral streams with their headwaters located totally within the Park boundaries.


Figure 1. The three major drainage basins of Zion National Park: the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek.

North Fork Watershed

The North Fork watershed receives the heaviest visitor use of the three drainages. This visitor use is restricted to the narrow canyon bottom and consists primarily of sightseeing, camping, and stream channel hiking. Flash flood threats and low water temperatures often restrict recreational water use to mid and late summer periods. These periods usually coincide with the periods of grazing use upstream of the park boundary.

This watershed represents a mosaic of land ownerships (Table 2). Private lands total 65 percent of the watershed, all of which lie upstream from Zion National Park. The most frequent land uses include cattle grazing, summer homes, and private hunting clubs.

This study measured the impact of cattle grazing on the water quality of the North Fork. Two sampling sites were located on the North Fork, one at the park boundary and another 2.5 miles upstream (Figure 2). The cattle grazing within this 2.5 mile reach is confined to narrow pasture lands adjacent to the North Fork. The cattle have free access to the stream.

Table 2. Land ownership of the North Fork of the Virgin River above the Zion National Park Headquarters (BLM, 1975).

| | Percent of total area | $Mi^2$ |
|---|---|---|
| Private Land | 65 | 236 |
| State Land | 3 | 10 |
| Federal Land | | |
| National Park Service | 21 | 78 |
| Bureau of Land Management | 9 | 32 |
| U.S. Forest Service | 2 | 8 |
| TOTAL | 100 | 364 |

East Fork Watershed

From a water quality perspective, the East Fork is the most complex of the three drainages. As can be seen from Figure 1, the drainage basin encompasses several small communities. These communities and their associated agricultural and livestock holdings are adjacent to the East Fork of the Virgin River. After passing through these communities, the East Fork flows through the most primitive and inaccessable section of the Park, Parunuweap Canyon. Thus, the drainage basin receives heavier use outside the Park than within the Park.

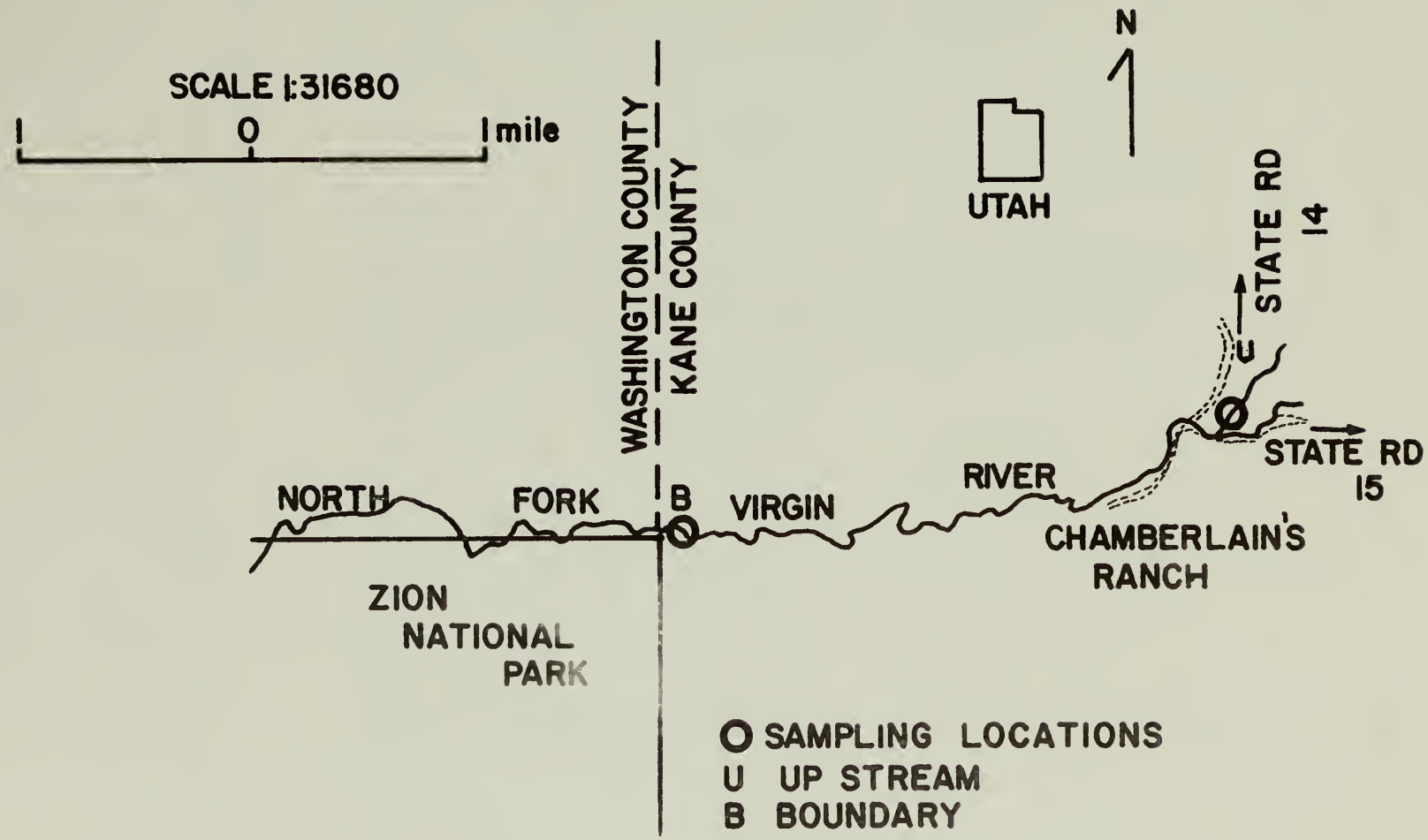



Figure 2. The location of the upstream (U) and boundary (B) sampling sites on the North Fork of the Virgin River.

LaVerkin Watershed

Like the North Fork, LaVerkin Creek drains private lands before entering National Park Service land. Here the private land use consists of cattle and sheep grazing. Grazing occurs between April and October and as many as 300 head of cattle and 600 head of sheep may be grazing per season within the basin headwaters (Greely 1977).

This area of the Park is referred to as the Kolob Section. Visitor use is light, compared to the North Fork section of the Park. Also, unlike the North Fork, visitors are not restricted to the active stream channel; they have much greater flexibility in selecting areas of use.

Sampling sites

Five sites were sampled: three on the North Fork and one each on the East Fork and LaVerkin Creek. The East Fork, LaVerkin Creek, and one of the North Fork sampling sites were located within Zion National Park. These sites were designed to measure the water chemistry and bacteria levels of the water resources within the Park. The remaining two sites on the North Fork were located outside the Park and were chosen to measure the bacterial inputs into the Park from upstream use. These two sites were located above and below specific land uses, as shown in Figure 3.

The parameters measured

Three bacterial indicators were measured: total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS). The physical parameters

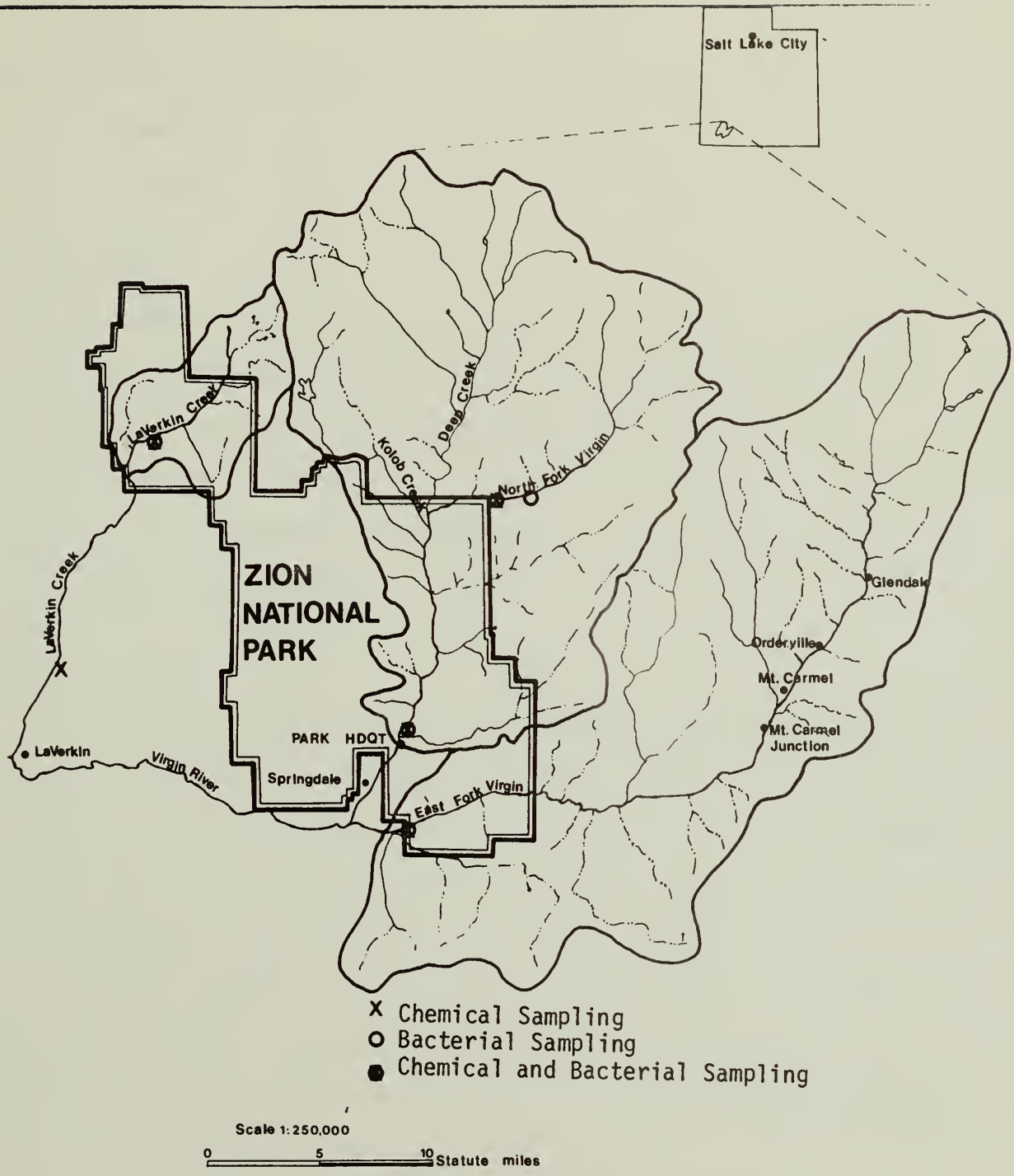



Figure 3. The chemical and bacterial samplings sites for the North Fork, East Fork, and LaVerkin Creek.

included turbidity and total dissolved solids. A broad spectrum of chemical elements were analyzed in addition to conductivitiy, alkalinity and total hardness.

Equipment used

The membrane filter technique was used for all bacterial analysis. Incubators, sample bags, filter holders, filter papers and procedures were used in accordance with Standard Methods 14th Edition (1976). M-FC and M-Endo growth mediums were taken from prepared ampules and used for the FC and TC incubations, respectively. M-enterococcus agar was used in the incubation of the FS.

Analysis of data

The bacterial samples were collected between 9:00 a.m. and 12:00 noon and were processed at the Park headquarters within 12 hours after collection. Colony identification and plate count methods were followed as outlined in Standard Methods (1976). Standard blanks were taken of the buffer water, filter holders, filter pads, and petri dishes.

One sample was taken at each site. From this sample, three replicates were taken for each of the bacterial indicators. This was done to determine the proper sample volume necessary to achieve the optimum plate count (Standard Methods 1976).

The chemical analyses, including conductivity and turbidity, were performed at Ford Chemical Laboratory in Salt Lake City. These samples were iced during transport and were delivered to Ford Laboratory within 24 hours after their collection.

# Results and Discussion

## Bacterial results

The results of the analysis for the three stations on the North Fork are given in Tables 3a, b, and c. For all three tables, bacterial concentrations are given for the boundary, the upstream and the headquarter locations. The total and fecal coliform concentrations measured at the upstream station were greater than the concentrations measured at the headquarters station (Table 3a and 3b). Table 3c shows a similar trend for the fecal strep concentrations.

Table 4 gives the mean concentration of the three bacterial indicators for the upstream and boundary stations. The percent increase in bacterial concentrations was then calculated using these means. The TC increase was the largest, 526 percent, and the FS increase was the lowest, 216 percent.

A group comparison of the mean bacterial concentrations was calculated for the upstream and boundary stations. This analysis indicates that the bacterial concentrations at the boundary station were greater than the bacterial concentrations at the upstream station. The concentration means for the two stations were found to be significantly different at the 95 percent or higher confidence level (Table 5).

Table 3a. Total coliform concentrations for the upstream, boundary, and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

| Date | Bacteria concentrations (colonies/100 ml) | | |
|---|---|---|---|
| | Upstream | Boundary | Headquarters |
| July 27, 1977 | 1,200 | 12,000 | no sample taken |
| 28 | 1,600 | 14,600 | 10,700 |
| 29 | 120 | 5,300 | no sample taken |
| 30 | 300 | 11,300 | 4,800 |
| 31 | 1,160 | 5,450 | no sample taken |
| Aug. 1, 1977 | 2,300 | 5,400 | 3,600 |
| 2 | 3,700 | 4,600 | 1,800 |
| 3 | 1,800 | 11,000 | 3,500 |
| 4 | 2,000 | 12,800 | 4,200 |
| Sept. 2, 1977 | 1,320 | 10,700 | 3,800 |
| 3 | 1,100 | 7,600 | 3,200 |
| 4 | 1,200 | 10,300 | 2,800 |

Table 3b. Fecal coliform concentrations for the upstream, boundary and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

| Date | Bacteria concentrations (colonies/100 ml) Upstream | Boundary | Headquarters |
|---|---|---|---|
| July 27, 1977 | 0* | 400 | no sample taken |
| 28 | 0* | 600 | 0* |
| 29 | 0* | 220 | no sample taken |
| 30 | 100* | 200 | 0* |
| 31 | 35 | 1,300 | no sample taken |
| Aug. 1, 1977 | 90 | 200 | 60 |
| 2 | 80 | 100* | 80 |
| 3 | 320 | 420 | 120 |
| 4 | 360 | 460 | 140 |
| Sept. 2, 1977 | 20* | 1,600 | 20* |
| 3 | 80* | 1,200 | 72 |
| 4 | 60 | 620 | 63 |

* The colony count was below the optimum range recommended by the Millipore Company and is thus less reliable than other values.

Table 3c. Fecal streptococcus concentrations for the upstream, boundary and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

| Date | Bacteria concentrations (colonies/100 ml) | | |
|---|---|---|---|
| | Upstream | Boundary | Headquarters |
| July 27, 1977 | 60 | 500 | no sample taken |
| 28 | 100* | 1,000 | 160 |
| 29 | 80 | 700 | no sample taken |
| 30 | 100* | 400 | 600 |
| 31 | 120 | 500 | no sample taken |
| Aug. 1, 1977 | 520 | 800 | 110 |
| 2 | 400 | 600 | 200 |
| 3 | 240 | 700 | 180 |
| 4 | 280 | 760 | 230 |
| Sept. 2, 1977 | 80* | 560 | 40 |
| 3 | 140 | 700 | 160 |
| 4 | 120 | 720 | 90* |

* The colony count was below the optimum range recommended by the Millipore Company and is thus less reliable than other values.

Table 4. Mean bacteria concentrations with percent increases for the upstream and boundary sampling stations.

| Bacteria | Bacteria concentration (colonies/100 ml) Upstream | Boundary | Percent increase |
|---|---|---|---|
| TC | 1,480 | 9,270 | 526% |
| FC[1] | 127 | 680 | 435% |
| FS | 190 | 600 | 216% |

[1] The sampling dates having "0" bacteria concentrations were not included in the mean calculations for either of the sampling locations.

Table 5. Group comparison of means and associated confidence levels for the upstream and boundary sampling stations.

| Bacterial parameter | Degrees of freedom | Computed[1] t | Table t[2] value at | percent confidence level |
|---|---|---|---|---|
| Total Coliform | 11 | 7.242 | 3.106 | 99% |
| Fecal Coliform | 8 | 2.707 | 2.306 | 95% |
| Fecal Strep. | 11 | 8.861 | 3.106 | 99% |

[1] Dixon, Wilfrid J. and Massey, Frank J. 1969. Introduction to Statistical Analysis. McGraw Hill, New York. p. 116.

[2] Dixon and Massey, p. 464.

The East Fork and LaVerkin Creek were also sampled for bacterial concentrations. Tables 6 and 7 give the bacterial results for these two streams. Samples were taken at three dates at each of the locations. These results are presented as summer baseline data and are not intended to represent trends or absolute concentrations.

Table 6. Bacteria concentrations for the East Fork of the Virgin River as measured near South Park boundary.

| Date | Bacteria Concentration (colonies/100ml) | | |
|---|---|---|---|
| | TC | FC | FS |
| July 26, 1977 | 2,700 | 620 | 270 |
| August 2, 1977 | 2,500 | 640 | 400 |
| September 2, 1977 | 2,300 | 580 | 360 |

Table 7. Bacteria concentrations for LaVerkin Creek, as measured at Lee Pass Trail, 1977.

| Date | Bacteria Concentration (colonies/100ml) | | |
|---|---|---|---|
| | TC | FC | FS |
| July 27, 1977 | 2,120 | 60 | 240 |
| August 2, 1977 | 1,400 | 360 | 200 |
| September 3, 1977 | 1,600 | 420 | 280 |

Bacteria discussion

The large increases in bacterial concentrations over the 2.5 mile reach of the North Fork indicate that the current land use does have an impact on the water quality. The statistical analysis of this report indicates that the two sampling points represent different populations. From bacterial analysis and field observations, the cattle grazing between the upstream and boundary sampling points have the greatest single impact on the water quality of the North Fork as it enters Zion National Park.

Once within the park, the North Fork bacterial concentration becomes diluted by tributary inflows. Previous studies (Maddox, 1977) have shown the bacterial concentrations of Deep Creek and Kolob Creek to be substantially lower than the bacterial concentrations of the North Fork for any given sampling day. This dilution effect accounts for the lower bacterial concentrations for the headquarter station when compared to the boundary concentration.

In 1975, the Utah State Division of Health published its suggested water quality criteria for swimming waters (Table 8). The upstream and boundary bacteria concentrations for both TC and FC exceed these suggested upper limits. The headquarters bacterial concentrations exceed the upper limits for TC, but not for FC. LaVerkin Creek and East Fork also exceed the upper limits for both TC and FC.

Table 8. Water quality standards for swimming waters, Utah State Division of Health (1975).

| Standard definition | Standard Number: Coliform Density (colony/100ml) | Standard Number: Fecal Coliform Density (colony/100ml) |
|---|---|---|
| Monthly mean may not exceed | 1000 | 200 |
| No more than 20% of samples collected in one month may exceed | 1000 | - |
| No more than 10% of samples collected in one month may exceed | 4000 | 400 |
| No more than 5% of samples collected in one month may exceed | 4000 | - |

Chemical results

Table 9 gives the chemical analysis for the North Fork. The three samples were taken during the summer months over a three year period. The sampling dates ranged from late spring runoff (May) to early fall. These concentrations suggest that many of the chemical parameters remain relatively constant throughout the sampling periods. This indicates that as flows increase the chemical inputs increase proportionately, thus the concentrations remain relatively constant throughout the sampling periods. This indicates that as flows increase the chemical inputs increase proportionately, thus the concentrations remain relatively constant.

Table 10 gives the recommended upper limits for swimming and fishery waters for several chemical elements. Sodium (as Na) in the only chemical parameter exceeding these limits. This exceedence is true for the three sampling dates. Sodium is common in most wildland waters with concentrations varying both locally and regionally. The human intake limits for sodium vary greatly, but unless the intake exceeds 1000 mg/l (Water Quality Crtieria, 1972), there is little concern.

However, fisheries are more susceptable to high sodium concentrations. McKee and Wolfe (1963) have found 10 mg/l concentration to be an acceptable upper limit for most fresh water fish.

Table 11 gives the water chemistry analysis for LaVerkin Creek. Three samples were taken during a single summer season. One sample was taken near the city of LaVerkin, the other two samples were taken within Zion National Park. Between the two sampling locations there are numerous agricultural lands, row crops, pasture lands, fruit trees, and

Table 9. Water quality data for the North Fork of the Virgin River near the Park headquarters.

| Water quality parameter | Sample dates | | |
|---|---|---|---|
| | Sept. 17, 1975 | July 23, 1976 | May 16, 1977 |
| Turbidity (JTU) | 4.2 | 20.0 | 2.00 |
| Conductivity (μmhos/cm) | 793.0 | 820.0 | 900.0 |
| pH | 7.14 | 7.56 | 7.81 |
| Total dissolved solids at 180°C. (mg/l) | 516.0 | 535.0 | 600.0 |
| Alkalinity as $CaCO_3$ (mg/l) | 158.0 | 231.0 | 168.0 |
| Aluminum as Al (mg/l) | <0.01 | 0.070 | 0.071 |
| Arsenic as As (mg/l) | <0.01 | 0.008 | <0.001 |
| Bicarbonate as $HCO_3$ (mg/l) | 191.49 | 202.5 | 204.9 |
| Barium as Ba (mg/l) | <0.01 | 0.144 | 0.091 |
| Boron as B (mg/l) | <0.01 | <0.001 | 0.22 |
| Cadmium as Cd (mg/l) | 0.002 | <0.001 | <0.001 |
| Calcium as Ca (mg/l) | 55.2 | 51.2 | 21.6 |
| Carbonate as $CO_3$ (mg/l) | <0.01 | <0.01 | <0.01 |
| Chloride as Cl (mg/l) | 88.0 | 90.0 | 130.0 |
| Chromium as Cr (Hex) (mg/l) | <0.01 | <0.001 | <0.001 |
| Cyanide as Cn (mg/l) | <0.01 | <0.01 | <0.01 |
| Copper as Cu (mg/l) | 0.02 | 0.006 | 0.007 |
| Fluoride as F (mg/l) | 0.13 | 0.32 | 0.28 |
| Total Hardness as $CaCO_3$ (mg/l) | 250.0 | 234.0 | 230.0 |
| Iron (Total) as Fe (mg/l) | 0.15 | 0.120 | 0.086 |
| Iron (Filtered) as Fe (mg/l) | 0.02 | 0.100 | 0.050 |
| Lead as Pb (mg/l) | <0.01 | 0.005 | <0.001 |
| Magnesium as Mg (mg/l) | 26.88 | 25.4 | 42.24 |
| Manganese as Mn (mg/l) | 0.01 | 0.035 | 0.034 |
| Mercury as Hg (mg/l) | <0.001 | <0.0002 | <0.0002 |
| Nitrate as $NO_3$-N (mg/l) | 0.04 | 0.02 | 0.10 |
| Phosphate as $PO_4$ (mg/l) | 0.100 | 0.065 | 0.035 |
| Potassium as K (mg/l) | 3.69 | 3.32 | 3.14 |
| Selenium as Se (mg/l) | <0.01 | 0.077 | <0.001 |
| Silica as $SiO_2$ (mg/l) | 4.15 | 9.9 | 21.5 |
| Silver as Ag (mg/l) | 0.007 | <0.001 | <0.001 |
| Sulfate as $SO_4$ (mg/l) | 85.50 | 92.0 | 82.0 |
| Sodium as Na (mg/l) | 57.00 | 73.0 | 122.50 |
| Zinc as Zn (mg/l) | 0.01 | 0.007 | 0.042 |

Table 10. Recommended upper limits of chemical concentrations for swimming and fishery waters (McKee and Wolfe, 1963).

| Chemical parameter | Recommended upper limit |
|---|---|
| Aluminum as Al (mg/l) | 0.50 |
| Arsenic as As (mg/l) | 0.10 |
| Barium as Ba (mg/l) | 5.00 |
| Boron as B (mg/l) | -- |
| Cadmium as Cd (mg/l) | -- |
| Calcium as Ca (mg/l) | 1000.00 |
| Chloride as Cl (mg/l) | 1500.00 |
| Chromium as Cr (Hex) (mg/l) | 5.00 |
| Cyanide as Cn (mg/l) | 0.05 |
| Copper as Cu (mg/l) | 0.10 |
| Fluoride as F (mg/l) | 5.0 |
| Iron (Total) as Fe (mg/l) | 0.20 |
| Iron (Filtered) as Fe (mg/l) | -- |
| Lead as Pb (mg/l) | 0.10 |
| Magnesium as Mg (mg/l) | 100.0 |
| Manganese as Mn (mg/l) | 40.0 |
| Mercury as Hg (mg/l) | 0.004 |
| Nitrate as $NO_3$-N (mg/l) | 4.20 |
| Phosphate as $PO_4$-P (mg/l) | 15.00 |
| Potassium as K (mg/l) | 50.00 |
| Selenium as Se (mg/l) | 2.0 |
| Silica as $SiO_2$ (mg/l) | 50.0 |
| Silver as Ag (mg/l) | 0.033 |
| Sulfate as $SO_4$ (mg/l) | 500.00 |
| Sodium as Na (mg/l) | 10.00 |
| Zinc as Zn (mg/l) | 0.10 |
| Conductivity (μmhos/cm at 25°C) | 2000.00 |

Table 11. Water quality data for La Verkin Creek near La Verkin, Utah and at Lee's Pass Trail.

| Water quality parameter | Sample location and date | | |
|---|---|---|---|
| | LaVerkin | Lee's Pass Trail | |
| | May 16, 1977 | Aug. 5, 1977 | Sept. 4, 1977 |
| Turbidity (JTU) | 3.0 | 1.5 | 2.0 |
| Conductivity (μmhos/cm) | 1,670.0 | 677.0 | 655.0 |
| pH | 7.62 | 7.97 | 7.80 |
| Total dissolved solids at 180°C. (mg/l) | 1,105.0 | 432.0 | 422.0 |
| Alkalinity as $CaCO_3$ (mg/l) | 180.0 | 148.0 | 152.0 |
| Aluminum as Al (mg/l) | 0.043 | 0.063 | 0.149 |
| Arsenic as As (mg/l) | <0.001 | <0.001 | <0.001 |
| Bicarbonate as $HCO_3$ (mg/l) | 219.6 | 180.6 | 185.4 |
| Barium as Ba (mg/l) | 0.048 | 0.063 | 0.184 |
| Boron as B (mg/l) | 0.22 | 0.15 | 0.04 |
| Cadmium as Cd (mg/l) | <0.001 | <0.001 | <0.001 |
| Calcium as Ca (mg/l) | 86.4 | 84.8 | 80.8 |
| Carbonate as $CO_3$ (mg/l) | <0.01 | <0.01 | <0.01 |
| Chloride as Cl (mg/l) | 16.0 | 8.0 | 10.0 |
| Chromium as Cr (Hex) (mg/l) | <0.001 | <0.001 | <0.001 |
| Cyanide as Cn (mg/l) | <0.01 | <0.01 | <0.01 |
| Copper as Cu (mg/l) | 0.005 | 0.002 | 0.004 |
| Fluoride as F (mg/l) | 0.40 | 0.20 | 0.15 |
| Total Hardness as $CaCO_3$ (mg/l) | 486.0 | 330.0 | 336.0 |
| Iron (Total) as Fe (mg/l) | 0.096 | 0.069 | 0.133 |
| Iron (Filtered) as Fe (mg/l) | 0.044 | 0.040 | 0.100 |
| Lead as Pb (mg/l) | <0.001 | <0.001 | <0.001 |
| Magnesium as Mg (mg/l) | 64.8 | 2.3293 | 32.16 |
| Manganese as Mn (mg/l) | 0.027 | 0.004 | 0.007 |
| Mercury as Hg (mg/l) | <0.0002 | <0.0002 | <0.0002 |
| Nitrate as $NO_3$-N (mg/l) | 0.36 | 0.010 | <0.01 |
| Phosphate as $PO_4$ (mg/l) | 0.045 | 0.010 | 0.01 |
| Potassium as K (mg/l) | 2.93 | 2.653 | 3.70 |
| Selenium as Se (mg/l) | <0.001 | <0.001 | <0.001 |
| Silica as $SiO_2$ (mg/l) | 26.0 | 7.0 | 8.0 |
| Silver as Ag (mg/l) | 0.005 | 0.014 | <0.001 |
| Sulfate as $SO_4$ (mg/l) | 580.0 | 202.0 | 194.0 |
| Sodium as Na (mg/l) | 143.0 | 17.10 | 11.93 |
| Zinc as Zn (mg/l) | 0.025 | 0.006 | 0.033 |

grain crops. Conductivity, total dissolved solids, total hardness, magnesium, sulfate and sodium all show marked increases. However, these increases cannot be totally attributed to agricultural use. The different dates of sampling and subsequent flow volumes may have an impact on these water chemistry variations.

With the exception of sodium, the water samples taken within the Park (Lee's Pass Trail) are within the recommended limits shown in Table 10. Sodium again exceeds this limit, but, as stated above, this becomes of concern only to fresh water fisheries. In this case, the LaVerkin Creek samples are only slightly above the recommended limit and would probably have little, if any, impact on the fisheries.

Table 12 gives the water chemistry for the East Fork. The two samples were taken in the summer of 1977 just upstream from the confluence of the East Fork and the North Fork. These results represent the upstream water use of the East Fork by the municipal and agricultural users in Glendale, Orderville, Mt. Carmel and Mt. Carmel Junction. In comparing these data with the recommended limits of Table 10, the sodium concentration once again exceeds the recommended limit.

The water chemistry of the North Fork changes as it flows through the Park. Table 13 illustrates the magnitude of the downstream change for one sampling day. On this particular day, 21 of the 34 chemical parameters increased, 8 remained unchanged, and 5 decreased in concentration. There are numerous variables that may account for these changes, not the least of which is the tributary inflow. The concentrations

Table 12. Water quality data for the East Fork of the Virgin River near the confluence with the North Fork of the Virgin River.

| Water quality parameter | Sampling dates | |
|---|---|---|
| | May 13, 1977 | Aug. 5, 1977 |
| Turbidity (JTU) | 2.50 | 1.6 |
| Conductivity (μmhos/cm) | 600.0 | 490.0 |
| pH | 7.73 | 8.10 |
| Total Dissolved Solids at 180° C. (mg/l) | 400.0 | 316.0 |
| Alkalinity as $CaCO_3$ (mg/l) | 150.0 | 148.0 |
| Aluminum as Al (mg/l) | 0.025 | 0.113 |
| Arsenic as As (mg/l) | <0.001 | <0.001 |
| Bicarbonate as $HCO_3$ (mg/l) | 183.0 | 180.6 |
| Barium as Ba (mg/l) | 0.038 | 0.040 |
| Boron as B (mg/l) | 0.14 | 0.17 |
| Cadmium as Cd (mg/l) | <0.001 | <0.001 |
| Calcium as Ca (mg/l) | 28.0 | 55.2 |
| Carbonate as $CO_3$ (mg/l) | <0.01 | <0.01 |
| Chloride as Cl (mg/l) | 24.0 | 24.0 |
| Chromium as Cr (Hex) (mg/l) | <0.001 | <0.001 |
| Cyanide as Cn (mg/l) | <0.01 | <0.01 |
| Copper as Cu (mg/l) | 0.003 | 0.002 |
| Fluoride as F (mg/l) | 0.35 | 0.17 |
| Total Hardness as $CaCO_3$ (mg/l) | 220.0 | 230.0 |
| Iron (Total) as Fe (mg/l) | 01079 | 0.125 |
| Iron (Filtered) as Fe (mg/l) | 0.050 | 0.100 |
| Lead as Pb (mg/l) | <0.001 | <0.001 |
| Magnesium as Mg (mg/l) | 36.0 | 22.08 |
| Manganese as Mn (mg/l) | 0.009 | 0.007 |
| Mercury as Hg (mg/l) | <0.0002 | <0.0002 |
| Nitrate as $NO_3$-N (mg/l) | 0.70 | 0.70 |
| Phosphate as $PO_4$ (mg/l) | 0.045 | 0.010 |
| Potassium as K (mg/l) | 2.97 | 3.57 |
| Selenium as Se (mg/l) | <0.001 | 0.003 |
| Silica as $SiO_2$ (mg/l) | 22.0 | 8.0 |
| Silver as Ag (mg/l) | <0.001 | <0.001 |
| Sulfate as $SO_4$ (mg/l) | 97.0 | 98.0 |
| Sodium as Na (mg/l) | 30.30 | 24.38 |
| Zinc as Zn (mg/l) | 0.020 | 0.008 |

Table 13. Water chemistry data for the North Fork of the Virgin River as measured at the headquarters and Chamberlain's Ranch, July 23, 1976.

| Parameter | Sampling location: Chamberlain's Ranch | Sampling location: Gage |
|---|---|---|
| Turbidity (JTU) | 15.0 | 20.0 |
| Conductivity (μmhos/cm) | 570.0 | 820.0 |
| pH | 7.60 | 7.56 |
| Total dissolved solids at 180°C. (mg/l) | 370.0 | 535.0 |
| Alkalinity as $CaCO_3$ (mg/l) | 206.0 | 234.0 |
| Aluminum as Al (mg/l) | 0.065 | 0.070 |
| Arsenic as As (mg/l) | <0.001 | 0.008 |
| Bicarbonate as $HCO_3$ (mg/l) | 251.3 | 202.5 |
| Barium as Ba (mg/l) | 0.089 | 0.144 |
| Boron as B (mg/l) | <0.001 | <0.001 |
| Cadmium as Cd (mg/l) | <0.001 | <0.001 |
| Calcium as Ca (mg/l) | 47.2 | 51.2 |
| Carbonate as $CO_3$ (mg/l) | <0.01 | <0.01 |
| Chloride as Cl (mg/l) | 4.0 | 90.0 |
| Chromium as Cr (Hex) (mg/l) | <0.001 | <0.001 |
| Cyanide as Cn (mg/l) | <0.01 | <0.01 |
| Copper as Cu (mg/l) | 0.005 | 0.006 |
| Fluoride as F (mg/l) | 0.30 | 0.32 |
| Total Hardness as $CaCO_3$ (mg/l) | 208.0 | 234.0 |
| Iron (Total) as Fe (mg/l) | 0.110 | 0.120 |
| Iron (Filtered) as Fe (mg/l) | 0.100 | 0.100 |
| Lead as Pb (mg/l) | <0.001 | 0.005 |
| Magnesium as Mg (mg/l) | 21.6 | 25.4 |
| Manganese as Mn (mg/l) | 0.025 | 0.035 |
| Mercury as Hg (mg/l) | <0.0002 | <0.0002 |
| Nitrate as $NO_3$-N (mg/l) | 0.05 | 0.02 |
| Phosphate as $PO_4$ (mg/l) | 0.035 | 0.065 |
| Potassium as K (mg/l) | 1.62 | 3.32 |
| Selenium as Se (mg/l) | 0.007 | 0.077 |
| Silica as $SiO_2$ (mg/l) | 15.0 | 9.9 |
| Silver as Ag (mg/l) | <0.001 | <0.001 |
| Sulfate as $SO_4$ (mg/l) | 18.7 | 92.0 |
| Sodium as Na (mg/l) | 18.7 | 73.0 |
| Zinc as Zn (mg/l) | 0.012 | 0.007 |

given in Table 13 serve to indicate possible directions of water chemistry changes with respect to time and location. These concentrations offer baseline water chemistry data.

## Conclusion and Recommendations

The following conclusions are the result of analyses of samples collected during the summers of 1976 and 1977.

1) The total coliform and fecal coliform concentrations of the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek all exceed the Utah State Division of Health recommended limits for swimming waters.

2) The bacterial concentrations within Zion National Park are influenced more by the uses outside the Park than the uses within the Park.

3) Cattle grazing, adjacent and upstream from the Park, does have an impact on the bacterial concentrations of the North Fork of the Virgin River.

4) Over a 2.5 mile reach of the North Fork of the Virgin River total coliform, fecal coliform and fecal streptococcus increased 526, 435 and 216 percent, respectively. These increases are attributed primarily to cattle grazing within the 2.5 mile reach outside the park.

5) With the exception of sodium, all of the measured chemical element concentrations were within the recommended limits for fresh water fisheries.

6) Because of the bacterial concentrations, recreationists should be made aware of the potential health hazards of human injestion of the waters of the North Fork, East Fork, and LaVerkin Creek.

## Literature Cited

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater. 14th ed. American Public Health Association, Inc., New York.

Buckhouse, John C. 1975. Water quality impact of burning and grazing on a chained pinyon-juniper site in southeastern Utah. Ph.D. dissertation, Utah State University, Logan, Utah.

Darling, L. A., and G. B. Coltharp. 1973. Effects of livestock grazing on the water quality of mountain streams. In: Proc. Symposium Water-Animal Relationships. Southern Idaho State College, Twin Falls, Idaho. June 1973:1-8.

Dixon, Wilfrid J., and Frank J. Massey, Jr. Introduction to Statistical Analysis. 3rd ed. McGraw Hill, New York, New York.

Environmental Protection Agency. 1972. Water quality criteria. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Greely, Hal. District Ranger, Zion National Park, Springdale, Utah. Personal Communication, August 1, 1977.

Kunkle, S. H. 1970. Sources and transport of bacterial indicators in rural streams. Presented at a symposium on the Interdisciplinary Aspects of Watershed Management, Montana State University, Bozeman, Montana. 3-6 August.

Kunkle, S. H. 1977. Using bacteria to monitor the influence of cattle wastes on water quality. (Unpublished).

Kunkle, S. H., and J. R. Meiman. 1967. Water quality of mountain watersheds. Hydrology Paper No. 21, Colorado State University, Fort Collins, Colorado.

McKee, J. E., and H. W. Wolf. 1963. Water Quality Criteria. California State Water Resources Control Board. California.

Mack, W. N. 1974. Investigations into occurrence of coliform organisms from pristine streams. Dept. of Microbiology and Public Health, Michigan State University, East Lansing, Michigan. (Unpublished data).

Maddox, J. D. 1977. Water Resource Inventory of Zion National Park. M.F. paper, Utah State University, Logan, Utah

Morrison, S. M., and J. F. Fair. 1966. Influence on environment on stream microbial dynamics, Hydrology Paper No. 13, Colorado State University, Fort Collins, Colorado.

Stuart, D. G., G. K. Bissonnette, T. D. Goodrich, and W. G. Walter. 1971. Effects of multiple use on water quality of high mountain watersheds: Bacteriological investigations of mountain streams. Journal of Applied Microbiology 22:1048-1054.

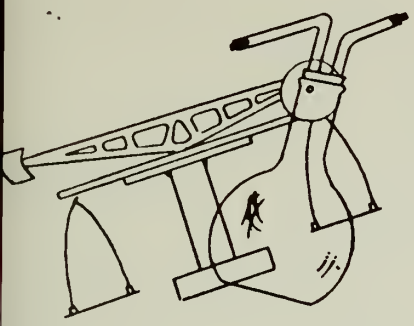
U.S. Department of Interior, Bureau of Land Management. 1976. State of Utah, Land Ownership and Public Management Map, Dixie-S.

Utah State Division of Health. 1976. Standards of quality for waters of the state. Utah.

Walter, W. G., and R. P. Bottman. 1967. Microbiological and chemical studies of an open and a closed watershed. Journal of Environmental Health 30:157-163.

# Appendix A

Chemical analysis of Zion National Park water resources as analyzed by Ford Chemical Laboratory, Inc. Salt Lake City, Utah



Ford Chemical
LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: October 6, 1975

Name Mr. George Hart

Address Forestry & Outdoor Recreation
Utah State University
Logan, UT 84321

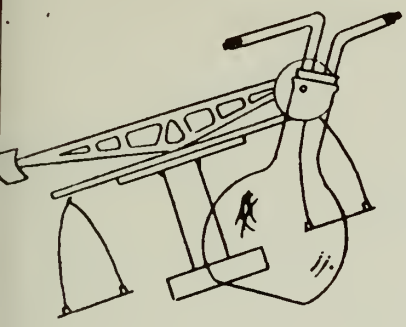
**CERTIFICATE OF ANALYSIS**

75-4199

Sample Water from North Fork of Virgin River at Highway 89 received on September 17, 1975.

| | | | |
|---|---|---|---|
| Turbidity | 4.2 JTU | Fluoride as F | 0.13 mg/l |
| Conductivity | 793.0 umhos/cm | Total Hardness as $CaCO_3$ | 250.0 mg/l |
| pH | 7.14 | Iron (Total) as Fe | 0.15 mg/l |
| Total Dissolved Solids at 180° C. | 516.0 mg/l | Iron (Filtered) as Fe | 0.02 mg/l |
| Alkalinity as $CaCO_3$ | 158.0 mg/l | Lead as Pb | <0.01 mg/l |
| Aluminum as Al | <0.01 mg/l | Magnesium as Mg | 26.88 mg/l |
| Arsenic as As | <0.01 mg/l | Manganese as Mn | 0.01 mg/l |
| Bicarbonate as $HCO_3$ | 191.49 mg/l | Mercury as Hg | <0.001 mg/l |
| Barium as Ba | <0.01 mg/l | Nitrate as $NO_3$—N | 0.04' mg/l |
| Boron as B | <0.01 mg/l | Phosphate as $PO_4$ | 0.100 mg/l |
| Cadmium as Cd | 0.002 mg/l | Potassium as K | 3.69 mg/l |
| Calcium as Ca | 55.2 mg/l | Selenium as Se | <0.01 mg/l |
| Carbonate as $CO_3$ | <0.01 mg/l | Silica as $SiO_2$ | 4.15 mg/l |
| Chloride as Cl | 88.0 mg/l | Silver as Ag | 0.007 mg/l |
| Chromium as Cr (Hex) | <0.01 mg/l | Sulfate as $SO_4$ | 95.50 mg/l |
| Cyanide as Cn | <0.01 mg/l | Sodium as Na | 57.00 mg/l |
| Copper as Cu | 0.02 mg/l | Zinc as Zn | 0.01 mg/l |

Ford Chemical Laboratory, Inc.



Ford Chemical
LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

**CERTIFICATE OF ANALYSIS**

76-5008

Sample Water at North Fork-Virgin River, Chamberlin Ranch Received on July 23, 1976 - Zion Park Research:

| | | | |
|---|---|---|---|
| urbidity | 15.0 JTU | Fluoride as F | 0.30 mg/l |
| Conductivity | 570.0 umhos/cm | Total Hardness as $CaCO_3$ | 208.0 mg/l |
| H | 7.60 | Iron (Total) as Fe | 0.110 mg/l |
| otal Dissolved Solids t 180° C. | 370.0 mg/l | Iron (Filtered) as Fe | 0.100 mg/l |
| lkalinity as $CaCO_3$ | 206.0 mg/l | Lead as Pb | <0.001 mg/l |
| luminum as Al | 0.065 mg/l | Magnesium as Mg | 21.6 mg/l |
| rsenic as As | <0.001 mg/l | Manganese as Mn | 0.025 mg/l |
| icarbonate as $HCO_3$ | 251.3 mg/l | Mercury as Hg | <0.0002 mg/l |
| arium as Ba | 0.089 mg/l | Nitrate as $NO_3$—N | 0.05 mg/l |
| oron as B | <0.001 mg/l | Phosphate as $PO_4$ | 0.035 mg/l |
| admium as Cd | <0.001 mg/l | Potassium as K | 1.62 mg/l |
| alcium as Ca | 47.2 mg/l | Selenium as Se | 0.007 mg/l |
| arbonate as $CO_3$ | <0.01 mg/l | Silica as $SiO_2$ | 15.0 mg/l |
| hloride as Cl | 4.0 mg/l | Silver as Ag | <0.001 mg/l |
| hromium as Cr (Hex) | <0.001 mg/l | Sulfate as $SO_4$ | 34.0 mg/l |
| yanide as Cn | <0.01 mg/l | Sodium as Na | 18.7 mg/l |
| opper as Cu | 0.005 mg/l | Zinc as Zn | 0.012 mg/l |

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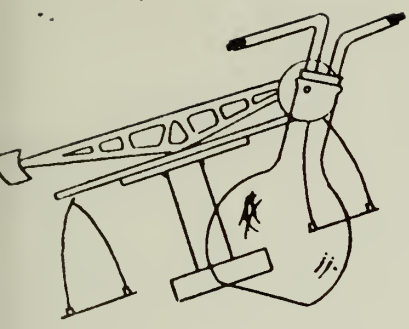

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LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

Name: Utah State University
ATTN: George Hart
Address: Forestry Science Laboratory
Logan, UT 84321

**CERTIFICATE OF ANALYSIS**

76-5010

Sample: Water labeled Deep Creek Received on July 23, 1976, Zion Park
Research:

| | | | |
|---|---|---|---|
| Turbidity | 7.5 JTU | Fluoride as F | 0.27 mg/l |
| Conductivity | 630.0 umhos/cm | Total Hardness as $CaCO_3$ | 180.0 mg/l |
| pH | 7.58 | Iron (Total) as Fe | 0.110 mg/l |
| Total Dissolved Solids at 180° C. | 410.0 mg/l | Iron (Filtered) as Fe | 0.100 mg/l |
| Alkalinity as $CaCO_3$ | 138.0 mg/l | Lead as Pb | <0.001 mg/l |
| Aluminum as Al | 0.130 mg/l | Magnesium as Mg | 15.84 mg/l |
| Arsenic as As | <0.001 mg/l | Manganese as Mn | 0.038 mg/l |
| Bicarbonate as $HCO_3$ | 168.4 mg/l | Mercury as Hg | <0.0002 mg/l |
| Barium as Ba | 0.089 mg/l | Nitrate as $NO_3$—N | <0.01 mg/l |
| Boron as B | <0.001 mg/l | Phosphate as $PO_4$ | 0.035 mg/l |
| Cadmium as Cd | 0.002 mg/l | Potassium as K | 1.58 mg/l |
| Calcium as Ca | 45.6 mg/l | Selenium as Se | 0.006 mg/l |
| Carbonate as $CO_3$ | <0.01 mg/l | Silica as $SiO_2$ | 0.90 mg/l |
| Chloride as Cl | 4.0 mg/l | Silver as Ag | <0.001 mg/l |
| Chromium as Cr (Hex) | <0.001 mg/l | Sulfate as $SO_4$ | 130.0 mg/l |
| Cyanide as Cn | <0.01 mg/l | Sodium as Na | 45.0 mg/l |
| Copper as Cu | 0.005 mg/l | Zinc as Zn | 0.008 mg/l |

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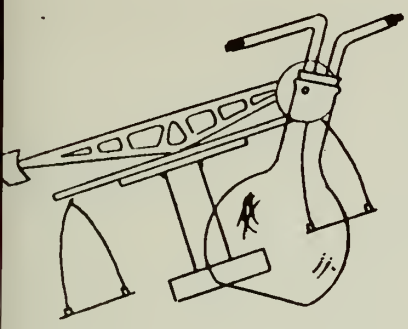

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*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

**CERTIFICATE OF ANALYSIS**

76-5009

Sample Water Labeled Kolob Creek Received on July 23, 1976-Zion Park
Research:

| | | | |
|---|---|---|---|
| Turbidity | 8.0 JTU | Fluoride as F | 0.30 mg/l |
| Conductivity | 480.0 umhos/cm | Total Hardness as $CaCO_3$ | 190.0 mg/l |
| pH | 7.70 | Iron (Total) as Fe | 0.080 mg/l |
| Total Dissolved Solids at 180° C. | 315.0 mg/l | Iron (Filtered) as Fe | 0.050 mg/l |
| Alkalinity as $CaCO_3$ | 158.0 mg/l | Lead as Pb | <0.001 mg/l |
| Aluminum as Al | 0.060 mg/l | Magnesium as Mg | 15.36 mg/l |
| Arsenic as As | <0.001 mg/l | Manganese as Mn | 0.030 mg/l |
| Bicarbonate as $HCO_3$ | 192.8 mg/l | Mercury as Hg | <0.0002 mg/l |
| Barium as Ba | 0.099 mg/l | Nitrate as $NO_3$—N | 0.04 mg/l |
| Boron as B | <0.001 mg/l | Phosphate as $PO_4$ | 0.035 mg/l |
| Cadmium as Cd | <0.001 mg/l | Potassium as K | 1.72 mg/l |
| Calcium as Ca | 50.4 mg/l | Selenium as Se | <0.001 mg/l |
| Carbonate as $CO_3$ | <0.01 mg/l | Silica as $SiO_2$ | 0.40 mg/l |
| Chloride as Cl | 4.0 mg/l | Silver as Ag | <0.001 mg/l |
| Chromium as Cr (Hex) | <0.001 mg/l | Sulfate as $SO_4$ | 45.0 mg/l |
| Cyanide as Cn | <0.01 mg/l | Sodium as Na | 10.0 mg/l |
| Copper as Cu | 0.011 mg/l | Zinc as Zn | 0.003 mg/l |

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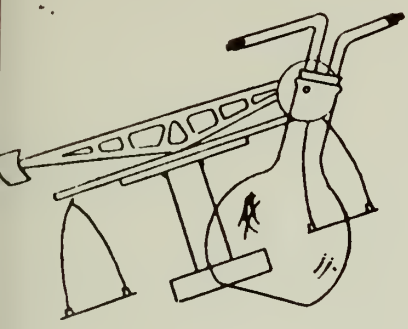

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*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, Utah 84321

**CERTIFICATE OF ANALYSIS**

76-5007

Sample Water Labeled Gage Received on July 23, 1976, Zion Park Research:

| | | | |
|---|---|---|---|
| Turbidity | 20.0 JTU | Fluoride as F | 0.32 mg/l |
| Conductivity | 820.0 umhos/cm | Total Hardness as $CaCO_3$ | 234.0 mg/l |
| pH | 7.56 | Iron (Total) as Fe | 0.120 mg/l |
| Total Dissolved Solids at 180° C. | 535.0 mg/l | Iron (Filtered) as Fe | 0.100 mg/l |
| Alkalinity as $CaCO_3$ | 234.0 mg/l | Lead as Pb | 0.005 mg/l |
| Aluminum as Al | 0.070 mg/l | Magnesium as Mg | 25.4 mg/l |
| Arsenic as As | 0.008 mg/l | Manganese as Mn | 0.035 mg/l |
| Bicarbonate as $HCO_3$ | 202.5 mg/l | Mercury as Hg | <0.0002 mg/l |
| Barium as Ba | 0.144 mg/l | Nitrate as $NO_3$—N | 0.02 mg/l |
| Boron as B | <0.001 mg/l | Phosphate as $PO_4$ | 0.065 mg/l |
| Cadmium as Cd | <0.001 mg/l | Potassium as K | 3.32 mg/l |
| Calcium as Ca | 51.2 mg/l | Selenium as Se | 0.077 mg/l |
| Carbonate as $CO_3$ | <0.01 mg/l | Silica as $SiO_2$ | 9.9 mg/l |
| Chloride as Cl | 90.0 mg/l | Silver as Ag | <0.001 mg/l |
| Chromium as Cr (Hex) | <0.001 mg/l | Sulfate as $SO_4$ | 92.0 mg/l |
| Cyanide as Cn | <0.01 mg/l | Sodium as Na | 73.0 mg/l |
| Copper as Cu | 0.006 mg/l | Zinc as Zn | 0.007 mg/l |

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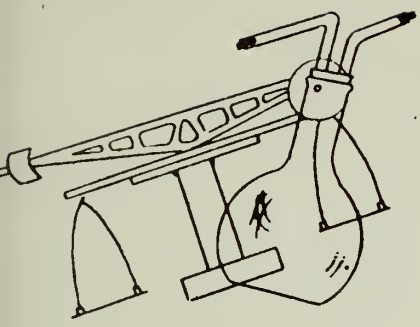



# Ford Chemical LABORATORY, INC.

*Bacteriological and Chemical Analysis*

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761


Date: June 6, 1977

Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

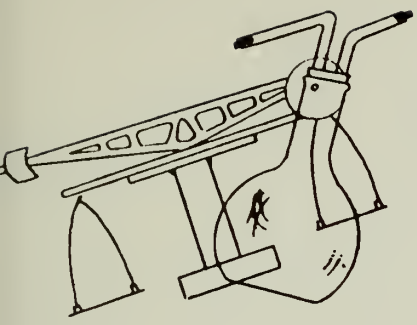
**CERTIFICATE OF ANALYSIS**

77-2632

Sample Water Labeled NF√R at Gage Received on May 16, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 2.00 JTU | Fluoride as F | 0.28 mg/l |
| Conductivity | 900.0 umhos/cm | Total Hardness as $CaCO_3$ | 230.0 mg/l |
| pH | 7.81 | Iron (Total) as Fe | 0.086 mg/l |
| Total Dissolved Solids at 180° C. | 600.0 mg/l | Iron (Filtered) as Fe | 0.050 mg/l |
| Alkalinity as $CaCO_3$ | 168.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.071 mg/l | Magnesium as Mg | 42.24 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.034 mg/l |
| Bicarbonate as $HCO_3$ | 204.9 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.091 mg/l | Nitrate as $NO_3$—N | 0.10 mg/l |
| Boron as B | 0.22 mg/l | Phosphate as $PO_4$ | 0.035 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 3.14 mg/l |
| Calcium as Ca | 21.6 mg/l | Selenium as Se | < 0.001 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 21.5 mg/l |
| Chloride as Cl | 130.0 mg/l | Silver as Ag | < 0.001 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 82.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 122.50 mg/l |
| Copper as Cu | 0.007 mg/l | Zinc as Zn | 0.042 mg/l |

Ford Chemical Laboratory, Inc.



Ford Chemical
LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: June 6, 1977

Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

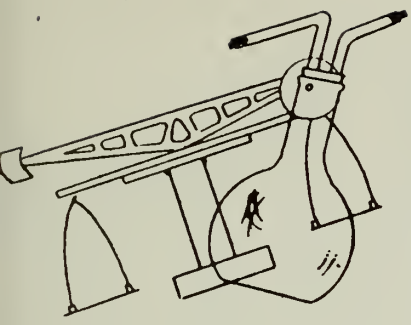
**CERTIFICATE OF ANALYSIS**

77-2633

Sample Water Labeled East Fork Virgin River at Confluence w/VR Dated May 13, 1977 Received on May 16, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 2.50 JTU | Fluoride as F | 0.35 mg/l |
| Conductivity | 600.0 umhos/cm | Total Hardness as $CaCO_3$ | 220.0 mg/l |
| pH | 7.73 | Iron (Total) as Fe | 0.079 mg/l |
| Total Dissolved Solids at 180° C. | 400.0 mg/l | Iron (Filtered) as Fe | 0.050 mg/l |
| Alkalinity as $CaCO_3$ | 150.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.025 mg/l | Magnesium as Mg | 36.0 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.009 mg/l |
| Bicarbonate as $HCO_3$ | 183.0 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.038 mg/l | Nitrate as $NO_3$—N | 0.70 mg/l |
| Boron as B | 0.14 mg/l | Phosphate as $PO_4$ | 0.045 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 2.97 mg/l |
| Calcium as Ca | 28.0 mg/l | Selenium as Se | < 0.001 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 22.0 mg/l |
| Chloride as Cl | 24.0 mg/l | Silver as Ag | < 0.001 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 97.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 30.30 mg/l |
| Copper as Cu | 0.003 mg/l | Zinc as Zn | 0.020 mg/l |

Ford Chemical Laboratory, Inc.



Ford Chemical
LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: June 6, 1977

Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

**CERTIFICATE OF ANALYSIS**

77-2634

Sample Water Labeled LaVerkin Creek at Hurricane Received on May 16, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 3.00 JTU | Fluoride as F | 0.40 mg/l |
| Conductivity | 1,670.0 umhos/cm | Total Hardness as $CaCO_3$ | 486.0 mg/l |
| pH | 7.62 | Iron (Total) as Fe | 0.096 mg/l |
| Total Dissolved Solids at 180° C. | 1,105.0 mg/l | Iron (Filtered) as Fe | 0.044 mg/l |
| Alkalinity as $CaCO_3$ | 180.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.043 mg/l | Magnesium as Mg | 64.8 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.027 mg/l |
| Bicarbonate as $HCO_3$ | 219.6 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.048 mg/l | Nitrate as $NO_3$-N | 0.36 mg/l |
| Boron as B | 0.22 mg/l | Phosphate as $PO_4$ | 0.045 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 2.93 mg/l |
| Calcium as Ca | 86.4 mg/l | Selenium as Se | < 0.001 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 26.0 mg/l |
| Chloride as Cl | 16.0 mg/l | Silver as Ag | 0.005 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 580.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 143.0 mg/l |
| Copper as Cu | 0.005 mg/l | Zinc as Zn | 0.025 mg/l |

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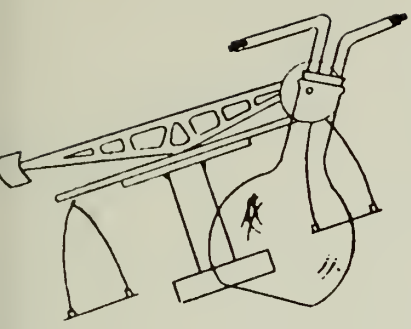

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LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 23, 1977

Name: Utah State University
Department of Forestry
Address: UMC 52
ATTN: Mr. George Hart
Logan, UT 84321

CERTIFICATE OF ANALYSIS
77-4237

Sample: Water Labeled East Fork Virgin River at North Fork Conf.; Received on August 5, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 1.6 JTU | Fluoride as F | 0.17 mg/l |
| Conductivity | 490.0 umhos/cm | Total Hardness as $CaCO_3$ | 230.0 mg/l |
| pH | 8.10 | Iron (Total) as Fe | 0.125 mg/l |
| Total Dissolved Solids at 180° C. | 316.0 mg/l | Iron (Filtered) as Fe | 0.100 mg/l |
| Alkalinity as $CaCO_3$ | 148.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.113 mg/l | Magnesium as Mg | 22.08 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.007 mg/l |
| Bicarbonate as $HCO_3$ | 180.6 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.040 mg/l | Nitrate as $NO_3-N$ | 0.70 mg/l |
| Boron as B | 0.17 mg/l | Phosphate as $PO_4$ | 0.010 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 3.57 mg/l |
| Calcium as Ca | 55.2 mg/l | Selenium as Se | 0.003 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 8.0 mg/l |
| Chloride as Cl | 24.0 mg/l | Silver as Ag | < 0.001 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 98.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 24.38 mg/l |
| Copper as Cu | 0.002 mg/l | Zinc as Zn | 0.008 mg/l |

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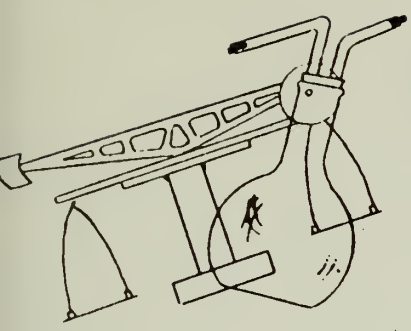

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LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485 5761

Date: August 23, 1977

Name Utah State University
Department of Forestry
Address UMC 52
ATTN: Mr. George Hart
Logan, UT 84321

CERTIFICATE OF ANALYSIS
77-4238

Sample Water Labeled Laverkin Creek at Lees Pass Trail Received on August 5, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 1.5 JTU | Fluoride as F | 0.20 mg/l |
| Conductivity | 677.0 umhos/cm | Total Hardness as $CaCO_3$ | 330.0 mg/l |
| pH | 7.97 | Iron (Total) as Fe | 0.069 mg/l |
| Total Dissolved Solids at 180° C. | 432.0 mg/l | Iron (Filtered) as Fe | 0.040 mg/l |
| Alkalinity as $CaCO_3$ | 148.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.063 mg/l | Magnesium as Mg | 2.3293 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.004 mg/l |
| Bicarbonate as $HCO_3$ | 180.6 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.063 mg/l | Nitrate as $NO_3$—N | 0.010 mg/l |
| Boron as B | 0.15 mg/l | Phosphate as $PO_4$ | 0.010 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 2.653 mg/l |
| Calcium as Ca | 84.8 mg/l | Selenium as Se | < 0.001 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 7.0 mg/l |
| Chloride as Cl | 8.0 mg/l | Silver as Ag | 0.014 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 202.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 17.10 mg/l |
| Copper as Cu | 0.002 mg/l | Zinc as Zn | 0.006 mg/l |

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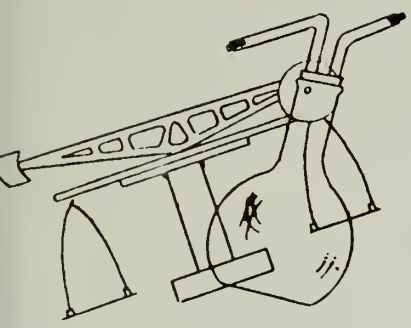

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LABORATORY, INC.
*Bacteriological and Chemical Analysis*
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: September 26, 1977

Name: Utah State University
Department of Forestry
Address: ATTN: Mr. George Hart
UMC 52
Logan, UT 84321

**CERTIFICATE OF ANALYSIS**

77-5017

Sample: Water Labeled "La Verkin Creek at Lee Pass Trail" Dated September 4, 1977; Received on September 6, 1977:

| | | | |
|---|---|---|---|
| Turbidity | 2.0 JTU | Fluoride as F | 0.15 mg/l |
| Conductivity | 655.0 umhos/cm | Total Hardness as $CaCO_3$ | 336.0 mg/l |
| pH | 7.80 | Iron (Total) as Fe | 0.133 mg/l |
| Total Dissolved Solids at 180° C. | 422.0 mg/l | Iron (Filtered) as Fe | 0.100 mg/l |
| Alkalinity as $CaCO_3$ | 152.0 mg/l | Lead as Pb | < 0.001 mg/l |
| Aluminum as Al | 0.149 mg/l | Magnesium as Mg | 32.16 mg/l |
| Arsenic as As | < 0.001 mg/l | Manganese as Mn | 0.007 mg/l |
| Bicarbonate as $HCO_3$ | 185.4 mg/l | Mercury as Hg | < 0.0002 mg/l |
| Barium as Ba | 0.184 mg/l | Nitrate as $NO_3$—N | < 0.01 mg/l |
| Boron as B | 0.04 mg/l | Phosphate as $PO_4$ | 0.01 mg/l |
| Cadmium as Cd | < 0.001 mg/l | Potassium as K | 3.70 mg/l |
| Calcium as Ca | 80.8 mg/l | Selenium as Se | < 0.001 mg/l |
| Carbonate as $CO_3$ | < 0.01 mg/l | Silica as $SiO_2$ | 8.0 mg/l |
| Chloride as Cl | 10.0 mg/l | Silver as Ag | < 0.001 mg/l |
| Chromium as Cr (Hex) | < 0.001 mg/l | Sulfate as $SO_4$ | 194.0 mg/l |
| Cyanide as Cn | < 0.01 mg/l | Sodium as Na | 11.93 mg/l |
| Copper as Cu | 0.004 mg/l | Zinc as Zn | 0.033 mg/l |

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